AN AUTOSTEREOSCOPIC DISPLAY METHOD

The present invention relates to a method of autostereoscopically displaying an N-viewpoint image on a screen having display image points or "pixels" disposed in rows and columns, each display pixel presenting $p > 1$ color points, corresponding to first, second, ..., and p^{th} color components, in which method the pixels of an autostereoscopic image to be displayed are displayed by distributing in space the $\underline{p}$ color points of each pixel amongst the color points of corresponding color components in $\underline{p}$ different display pixels.

BACKGROUND OF THE INVENTION

Such a method is described in PCT application WO 94/26072 filed in the name of the Applicant under the title "An autostereoscopic video device and system", published on November 10, 1994. In that method relating to the case where the video screen pixels are made up of $\underline{p}$ color points placed side by side in the row direction, the $\underline{p}$ (e.g. two or three) color components (or color points) for a single image point or pixel in an autostereoscopic image having N viewpoints are distributed over $\underline{p}$ (e.g. two or three) successive pixels arranged in the row direction of the image. The number N of viewpoints for the image is not a multiple of $\underline{p}$, and the lens array has a pitch equal to the product of the color point pitch multiplied by the number of viewpoints.

A method implementing the same principle is described in European patent application No. 0 791 847 (Philips Electronics) entitled "Autostereoscopic display apparatus", published on August 27, 1997. In that method, which seeks to distribute the loss of definition due to having multiple images over both the rows and the columns, the pixels are offset from one row to another by a distance equal to half the pitch of the color points making up the pixels, said offsets being obtained optically in that case by inclining the lenses of the

display array relative to the column direction of the display pixels of the screen.

The methods described in the documents mentioned above do not make it possible to compensate, at least in part, the loss of definition due to the presence of N viewpoints.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a display method enabling the above-specified problem to be remedied, at least in part.

The present invention thus provides a method of autostereoscopically displaying an N-viewpoint image on a screen having display pixels disposed in rows and columns, each display pixel presenting $p > 1$ color points, corresponding to first, second, ..., and p^{th} color components, in which method the pixels of an autostereoscopic image to be displayed are displayed by distributing in space the p color points of each pixel amongst the color points of corresponding color components in p different display pixels, wherein, starting from a "high definition" autostereoscopic image presenting at least as many pixels each having p color points as the N viewpoint image presents color points, a said autostereoscopic image to be displayed is generated in which each pixel is a color point of the corresponding color component from p different pixels in the high definition autostereoscopic image.

The distribution between p pixels of the image to be displayed is then implemented on the basis of p different pixels of the high definition autostereoscopic image, whereas in the above-mentioned prior art, this distribution was performed on the basis of p color points coming from the same image point or pixel.

The autostereoscopic image to be displayed can be generated from the high definition image upstream from the screen in a memory or on any recording medium, or else directly by addressing at screen level.

Preferably, the high definition autostereoscopic image presents in the row direction as many pixels each having p color points as each image row presents color points.

5   Given that the p color components of each pixel carry information coming from p points that are distributed in space, the resulting image presents resolution that is p times better in terms of brightness, whereas color definition has the same resolution as

10   before. The spectator nevertheless perceives an image which subjectively presents definition that is improved by p times because of the improved perception of outlines, whereas the lower definition of the color ("smearing" color effect) is not perceived in

15   stereoscopic vision.

For example, in an image presenting a sloping line segment, the offset between the color components, e.g. red, green, and blue, of the pixels that follow one another in the "high definition" image and that is due to

20   said distribution in space of the original information about the various display pixels, is, in the presence of contrast, perceived by the brain more as a high resolution difference in brightness than as a periodic variation in color. In addition, the spatial

25   distribution of color points has the effect that the two eyes, which see two different viewpoints, generally see different color components through a given lens, thus inducing complementarity from one eye to the other which attenuates perception of the low resolution of the color

30   components. The overall subjective effect is an improvement in the fineness of the image and in the perception of planes (due to the increase in disparity resolution), and the lower color resolution is practically not perceived.

35   An autostereoscopic image intrinsically presenting high definition can be obtained from a camera, or from an

image library, or indeed in the form of synthesized images.

The high definition autostereoscopic image can be generated from a starting autostereoscopic image which presents definition lower than said high definition by using a definition-increasing method, such as an interpolation method, a vectorization method, or an outline search method. The starting autostereoscopic image can be obtained from a camera or from an image library, or indeed in the form of synthesized images.

This makes it possible to benefit from the improvement in image definition that can be obtained by modern methods for processing images digitally. In particular, said lower definition can be the definition of the screen, thus making it possible in particular to start from standard video images.

The high definition autostereoscopic image may be generated by generating for each pixel only the color point that is used when generating said autostereoscopic image to be displayed.

The definition increasing method can increase definition in the row direction and/or in the column direction.

In an embodiment applicable to the display technique described in above-mentioned European patent application No. 0 791 847, and enabling definition to be increased both in the row direction and in the column direction, the high definition autostereoscopic image can be obtained from a starting autostereoscopic image by using said definition-increasing method to generate an intermediate autostereoscopic image presenting either p or p-1 times as many rows and p or p-1 times as many columns of pixels than the screen, and said high definition autostereoscopic image can be obtained by selecting those pixels in the intermediate autostereoscopic image whose positions correspond to said distribution in space.

In the context of this technique, it nevertheless remains advantageous to increase definition in the horizontal or row direction only.

It is advantageous, in particular when said lower definition is screen definition to increase definition by generating an intermediate autostereoscopic image having increased definition that is lower than said high definition, and from which said high definition autostereoscopic image is generated. This applies in particular when p = 3 and the increased definition image has p-1 (i.e. two) times as many pixels as the starting autostereoscopic image, whereas the high definition autostereoscopic image has p = 3 times as many pixels as the starting autostereoscopic image.

The intermediate autostereoscopic image and/or the high definition image are preferably generated by computing for each pixel only those color points which are "useful", i.e. those which are used in subsequent computations and/or for display.

In a variant of the invention enabling definition to be increased both in the row direction and in the column direction, wherein the high definition autostereoscopic image is obtained from a starting autostereoscopic image having either p or p-1 times as many lines and either p or p-1 times as many columns of pixels than the screen, and wherein the high definition autostereoscopic image is obtained by selecting pixels from the starting autostereoscopic image whose positions correspond to said distribution in space. The same remarks apply as above.

In a particularly advantageous variant, said autostereoscopic image to be displayed, when ordered so as to interleave the pixels of the N viewpoints making it up in accordance with its display topology, comprises groups of N pixels each of which corresponds to a different viewpoint to form an interleaved image as described in the Applicant's PCT application WO 94/26072, the first pixel of a given N pixel group corresponding to

a first viewpoint being constituted by a first color
point which is the color point of the first color
component of the first of said p different pixels of a
group of p pixels of the first viewpoint, a second color

5 point which is the color point of the second color
component of the second of said different pixels of said
group of p pixels of the first viewpoint, ..., and a pth
color point which is the color point of the pth color
component of the pth of said different pixels of said

10 group of p pixels of the viewpoint, the second pixel of
said given group of N pixels which corresponds to a
second viewpoint being constituted by a first color point
which is the color point of the second color component of
the first of said p different pixels of a group of p

15 pixels of the second viewpoint, ..., and a pth color point
which is the color point of the first color component of
the pth of said p different pixels of the group of p
pixels of the second viewpoint, ..., and so on by
circular permutation to the Nth pixel of said given group

20 which corresponds to the Nth viewpoint and to the group of
p pixels corresponding thereto. Said groups of N pixels
are advantageously repeated in the row direction.

Said p different pixels can be contiguous.

Preferably, said p different pixels are in alignment

25 in the row direction.

The p color points of each display pixel are
advantageously placed side by side in the column
direction, or preferably in the row direction.

The invention also provides an N viewpoint

30 autostereoscopic image presenting pixels disposed in rows
and columns, each pixel being constituted by p color
points of a different color component, wherein each of
the p color points of each pixel is constituted by a
color point of a corresponding color component offset in

35 space in the same manner for each of the p different
pixels of a group of p pixels of a viewpoint of a high
definition autostereoscopic image presenting at least as

many pixels having $\underline{p}$ color points as the N viewpoint
autostereoscopic image presents color points. Said $\underline{p}$
different pixels are advantageously contiguous and they
are preferably in alignment in the row direction. They
5 can also be in alignment, for example, along a diagonal
of the high definition autostereoscopic image.

When the image is ordered in such a manner as to
interleave the pixels of the N viewpoints making it up in
accordance with the topology of its display, the image
10 can comprise groups of N pixels each of which corresponds
to a different viewpoint, the first pixel of a given
group of N pixels which corresponds to a first viewpoint
being constituted by a first color point which is the
color point of the first color component of the first of
15 said $\underline{p}$ different pixels of a $\underline{p}$-pixel group of the first
viewpoint, a second color point which is the color point
of the second color component of the second of said
different pixels of the said $\underline{p}$-pixel group of the first
viewpoint, ..., and a pth color point which is color point
20 of the pth color component of the pth of said different
pixels of said $\underline{p}$-pixel group of the viewpoint, the second
pixel of said given group of N pixels which corresponds
to a second viewpoint being constituted by a first color
point which is the color point of the second color
25 component of the first of said $\underline{p}$ different pixels of a $\underline{p}$-
pixel group of the second viewpoint, ..., and a pth color
point which is the color point of the first color
component of the pth of said $\underline{p}$ different pixels of said $\underline{p}$
pixel group of the second viewpoint, and so on by
30 circular permutation to the Nth pixel which corresponds to
the Nth viewpoint and to the $\underline{p}$-pixel group corresponding
thereto.

The invention also provides an image displayed or
printed on a medium, the image being displayed or printed
35 from an autostereoscopic image in the form of display
points or pixels which are obtained by distributing the $\underline{p}$
color points of each pixel of said autostereoscopic image

between the color points of corresponding color components of $\underline{p}$ different display pixels.

The invention also provides a recording medium such as a hard disk, a DVD disk, or a magnetic tape presenting

5   at least one recorded autostereoscopic image, as defined above.

Finally, the invention provides a transmission system in particular via cables or radio links, essentially by satellite, including a transmitter device

10   for transmitting autostereoscopic images as defined above.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantage of the invention will appear better on reading the following description

15   given by way of non-limiting example and with reference to the accompanying drawings, in which:

· Figure 1 shows a first variant of the invention applied to the case shown in Figure 1a of the above-cited PCT application WO 94/26072, and Figures 2 and 3 show

20   variants corresponding respectively to 5 and to 7 viewpoints;

· Figure 4 shows a second variant of the invention applied to the case shown in Figure 1b of the above-cited PCT application;

25   · Figure 5 shows a third variant of the invention applied to the case shown in Figure 1a of the above-cited PCT application, with image definition being increased in two stages;

· Figures 6a and 6b show a fourth variant of the

30   invention, corresponding to the case shown in Figures 4A and 4B of the above-cited European application No. 0 791 847;

· Figures 7a and 7b show a fifth variant of the invention, corresponding to the case shown in Figures 5A

35   and 5B of European application No. 0 791 847;

· Figures 8a and 8b show a sixth variant of the invention, corresponding to the case shown in Figures 6A and 6B of European application No. 0 791 847; and

· Figure 9 shows definition being increased by computing intermediate pixels, starting from an image of lower definition.

MORE DETAILED DESCRIPTION

In Figure 1, corresponding to $N = 4$ and $p = 3$, the high definition image has three times as many pixels in the row direction as the standard image used in Figure 1a of PCT application WO 94/26072. To facilitate description, it is shown in the form of an interleaved image comprising, in the row direction, groups of $p = 3$ pixels, i.e. the three first pixels T_1, T_2, T_3 of the first viewpoint PV1, the first three pixels T_1, T_2, T_3 of the second viewpoint PV2, the first three pixels T_1, T_2, T_3 of the third viewpoint PV3, the three first pixels T_1, T_2, T_3 of the fourth viewpoint PV4, and then the next three pixels T_4, T_5, T_6 of PV1, the next three pixels T_4, T_5, T_6 of PV2, etc.

In the row direction the screen presents display pixels P1, P2, P3, ..., PM, each made of $p = 3$ color points corresponding to the red R, green G, and blue B color components. The lens array 10 has lenses L1, L2, L3, ... at a pitch equal to four times the pitch of the color points in the display pixels, which means that the first lens L1 is situated in register with the components R, G, and B of P1 and the component R of P2, lens L2 is situated in register with the components G and B of P2 and the components R and G of P3, and so on.

Instead of distributing the R, G, and B components of the first pixel of the standard image between the points of corresponding color components of the pixels P1, P2, and P3 respectively, in the invention this distribution is performed by conserving only one of the color points of each of the pixels T_1, T_2, T_3 of the first viewpoint PV1, respectively for the colors R, G, and B.

The same applies with circular permutation of the color
components for the first three pixels T_1, T_2, T_3 of the
other viewpoints PV2, PV3, and PV4.

For viewpoint PV1, the R color point of T_1 is
5   displayed at the corresponding R color point of P1, the G
color point of T_2 is displayed at the corresponding G
color point of P2, and the B color point of T_3 is
displayed at the corresponding B color point of P3. The
R color point of T_1, G of T_2, and B of T_3 thus constitute
10 a display triplet TR1 representing the first pixel of the
image to be displayed.

For viewpoint PV2, the G color points of T_1, B of T_2
and R of T_3, which constitute a triplet TR2 representing
the second pixel of the image to be displayed are
15 displayed respectively at the G color point of P1, B of
P2, and R of P4. For viewpoint PV3, the B color point of
T_1, R of T_2, and G of T_3, which constitute a triplet TR3
are respectively displayed at the B color point of P1, R
of P3, and G of P4. For viewpoint PV4, the R color point
20 of T_1, G of T_2, and B of T_3, which constitute a triplet
TR4 are respectively displayed at the R color point of
P2, G of P3, and B of P4, thereby terminating the
sequence. The sequence is repeated for the R color point
of T_4, G of T_5, and B of T_6 which constitute the triplet
25 TR5, for viewpoint PV1, which are displayed respectively
at the R color point of P5, G of P6, and B of P7, and so
on. This distribution in space starting from an image
having three times as many pixels in the row direction
serves to increase the brightness definition of the image
30 while conserving its color definition. At a nominal
viewing position, an observer sees either viewpoint PV1
and PV3 or viewpoints PV2 and PV4. In the first case,
the left eye sees the R, G, and B components through
three successive lenses while the right eye sees the B,
35 R, and G components. In the second, the left eye sees
the G, B, and R components in three successive lenses
while the right eye sees the R, G, and B components. The

same applies when the observer is in a position to see viewpoints PV1 & PV2, or PV2 & PV3, or PV3 & PV4.

This complementary effect between the eyes and between the lenses makes it possible, as stated above, to attenuate the perceived impact of low color resolution in stereoscopic vision.

Figure 2 corresponds to the case where there are five viewpoints (N = 5). The pitch of the lenses L1, L2, ... of the array 10 is equal to N = 5 times the pitch of the color points of the display pixels P1, P2, ... For viewpoint PV1, the triplet TR1 which represents the first pixel of the image to be displayed is constituted by the red component of the first pixel T_1 written $T_1(R)$, the blue component of the second pixel T_2 written $T_2(B)$, and the green component of the third pixel T_3 written $T_3(G)$. $T_1(R)$ is displayed at the red color point R of display pixel P1, $T_2(B)$ is displayed at the blue color point of P2, and $T_3(G)$ is displayed at the green color point of P4. The display rule is represented in Figure 2 in the form of a table. The triplets TR1, TR2, TR3, TR4, and TR5 correspond respectively to viewpoints PV1, PV2, ..., PV5. The triplets TR6, ..., TR10 correspond respectively to viewpoints PV1, ..., PV5, and so on, modulo 5.

Figure 3 corresponds to the case where there are seven viewpoints (N = 7). The pitch of the lenses L1, L2, ... of the array 10 is now equal to seven times the pitch of the color points of the display pixels P1, P2, ... The presentation in the form of a table is similar to that of Figure 2. The triplets TR1, ..., TR7 correspond respectively to viewpoints PV1, ..., PV7, and so on, modulo 7.

Figure 4 shows the case (p = 2) where the screen pixels are made up of two color components placed side by side in the horizontal or row direction, specifically an (R, G) color component constituted by vertically superposing a red component R and a green component G of half-intensity, and a (G, B) color component constituted

by vertically superposing a half-intensity green
component G and a blue component B. The lens array has
lenses L' at a pitch equal to N = 3 times the pitch of
the color components. The increase in definition is

5   obtained from an image having twice as many pixels in the
row direction as the standard image used in Figure 1b of
PCT application WO 94/26072.

For viewpoint PV1, the display triplet TR1 is
constituted by the (R, G) color component of pixel T_1 of

10   viewpoint PV1 of the image to be displayed, and the (G,
B) color component of pixel T_2 of viewpoint PV1 of the
image to be displayed. For viewpoint PV2, the display
triplet TR2 is constituted by the (G, B) color component
of pixel T_1 of viewpoint PV2, and by the (R, G) color

15   component of pixel T_2 of viewpoint PV2. The (R, G)
component of pixel T_1 of PV1 is displayed as the (R, G)
component of the display pixel P'1. The (G, B) component
of pixel T_2 of PV1 is displayed as the (G, B) component of
pixel P'2. The (G, B) component of pixel T_1 of PV2 is

20   displayed as the (G, B) component of pixel P'1. The (R,
G) component of pixel T_2 of PV2 is displayed as the (R, G)
component of pixel P'3, and so on. In the nominal
viewing position, either the left eye sees viewpoint PV1
and the right eye sees viewpoint PV2, or the left eye

25   sees viewpoint PV2, and the right eye sees viewpoint PV3.
In the first case, the left eye sees the (R, G) and (G,
B) components in successive lenses while the right eye
seeks the (G, B) and (R, G) components in the same
lenses. In the second case, the left eye sees the (G, B)

30   and (R, G) components in successive lenses while the
right eye sees the (R, G) and the (G, B) components in
the same lenses.

The colors are thus complementary between one eye
and the other and between one lens and the other, but in

35   this case for the three components having the colors red,
green, and blue, which is favorable from the point of
view of perception.

Figure 5 shows the same case as Figure 1 except that the image to be displayed is generated from an "intermediate" autostereoscopic image having definition in the row direction that is twice, and not three times
5   that of a standard image of the kind used in Figure 1a of PCT application WO 94/26072. This intermediate image can be an image provided by a camera, or it can be an image coming from a video data library, or indeed an image computed by increasing definition from a standard image.
10   The intermediate image can also be a synthesized image.

If it is desired to retain image information during display, it is necessary to compute three color components for display for each viewpoint starting from a pair of pixels T_1 and T_2, T_3 and T_4, etc.

15   In the example shown, this is done by linear interpolation using three successive pixels T_1, T_2, T_3; T_3, T_4, T_5, etc.

The $T_1(R)$ component of PV1 is displayed as the R component of P1. The interpolated component:
20

$$\frac{T_1(G)}{3} + \frac{2T_2(G)}{3}$$

is displayed as the G component of P2.

The interpolated component:

25

$$\frac{2T_2(B)}{3} + \frac{T_3(B)}{3}$$

is displayed as the blue component of P3, and so on, as shown in the form of a table in Figure 5.

The method in the variants described above can be applied directly to improving definition in the row
30   direction of the device described in European application No. 0 791 847. In the context of Figures 4A, 4B, 6A, and 6B of that application, definition can be increased by a factor of three. In the case shown in Figures 5A and 5B, it can be increased by no more than a factor of two.

To increase definition both in the row direction and in the column direction, the starting point is an image whose definition is higher in both directions.

In Figures 6a and 6b, definition is increased by a
5   factor of 3, both in the row direction and in the column direction. Thus, the first pixel to be displayed for viewpoints PV1, PV2, ..., is constituted by a matrix of nine pixels T_{11}, ..., T_{33}. For PV1, the useful components are the red component $T_{11}(R)$ of T_{11}, the green component
10   $T_{22}(G)$ of T_{22}, and the blue component $T_{33}(B)$ of T_{33}. For PV2, the useful components are the green component $T_{11}(G)$ of T_{11}, the blue component $T_{22}(B)$ of T_{22}, and the red component $T_{33}(R)$ of T_{33}, and so on. To generate the image to be displayed, it is necessary to compute the useful
15   components only for display purposes.

In Figures 7a and 7b, definition is increased by a factor of 2 in the row direction and by a factor of 3 in the column direction. The pixels to be displayed for the first viewpoint are the components $T_{11}(R)$, $T_{21}(G)$, and
20   $T_{31}(B)$. For the other viewpoints, the components to be retained can be deduced by permutation.

In the case shown in Figures 8a and 8b, definition is increased by a factor of 3 in the row direction and by a factor of 2 in the column direction. For the first
25   pixel to be displayed for each viewpoint, the components $T_{11}(R)$, $T_{22}(B)$, and $T_{13}(G)$ are retained. For the other viewpoints, the components to be retained are deduced by permutation.

Figure 9 shows definition being increased by a
30   factor of 3 in the row direction starting from an image in "N image" mode as described in the Applicant's PCT application WO 94/26071, and in which the pixels written T_1, T_4, T_7, ..., T_M are represented conventionally by a dot of larger size. For each of the original pixels T_1, T_4,
35   T_7, ..., T_M for each viewpoint or elementary image, two intermediate pixels (T_2, T_3), (T_5, T_6), etc. are computed, e.g. by interpolation, so as to increase definition.

The method of the invention makes it possible, starting from images of standard video definition, or from images that intrinsically present higher definition, whether filmed images or synthesized images made using
5   the method described in the Applicant's PCT application WO 97/01250, to generate autostereoscopic images having definition that is improved in terms of brightness and that is lower in terms of chrominance.

Each pixel of the autostereoscopic image to be
10 displayed contains information coming from p different points in space. Such an autostereoscopic image for display can also be generated directly from the image supplied by a camera fitted with a single CCD sensor and presenting color filters that follow one another
15 horizontally (RGBRGBRGB, ...) and a diverging lens array whose apparent array pitch (i.e. the pitch of the lens array as projected by the optical system for transferring the image onto the single CCD sensor) is equal to that of N color filters, or a converging lens array with
20 symmetrical permutation of groups of N color filters so as to conserve autostereoscopy. For example, for N = 4, at a pitch of 12, the following permutation occurs RBGRGRBGBGRB, etc. This achieves the desired space offset for each of the color points of the
25 autostereoscopic image to be displayed. Image-transferring lens array cameras are described in particular in the Applicant's PCT applications WO 97/26071 and WO 94/25891.

Such an image can be used in a transmission system
30 or it can be recorded on a recording medium such as a hard disk, a DVD disk, a magnetic tape, etc. The image can be displayed on a screen having a lens array placed in front of it. It can also be printed on a paper medium and images can then be seen in relief by using a suitable
35 lens array which can optionally be secured to the paper medium.

　　　　In the description above, the terms "row" and "column" mean respectively the horizontal lines and the vertical lines of pixels as seen by a sitting or standing observer, independently of the direction in which the display screen is scanned which can either be horizontal or vertical. For example, for a screen whose scan lines are vertical, then those lines are considered as being "columns".